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ILLUMINATING ENGINEERING SOCIETY

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The Application of Modern Flash Discharge Tubes*

By C. R. BICKNELL, B.Sc., *(Fellow)*

Synopsis

A flash discharge tube is a light source that is designed to be operated by a condenser discharge, and thus to produce flashes of very high intensity and very short duration. It may be operated in conditions in which these flashes are isolated from one another by relatively long periods of time, or in which they follow one another in rapid succession.

The high current density conditions of operation result in the production of light of excellent spectral quality, whilst the flash duration is so short as to be capable of arresting very high speed motion.

It is not practicable, within the compass of a paper such as this, to refer to all the manifold purposes to which flash discharge tubes can be usefully applied. It has, therefore, been the author's endeavour to discuss flash tube applications on broad rather than specific lines and to cite particular applications as examples of general practice.

Introduction

Electric light sources are commonly divided into such groups as general lighting service, electric discharge, projector lamps and so forth, but, for the purpose of the present paper, it is appropriate to make an even broader subdivision into two categories only—those that produce a continuous light throughout their useful life and those designed to emit light in pulses. In the second category there are lamps in which a single flash of light represents the total life of the source, as in the case of photographic flash bulbs, operating by the oxidation of foil or wire. Other lamps, designed for pulse operation, are capable of repeating the flash at the will of the operator, and it is with this class of so-called flash discharge tubes that this paper is concerned.

During the recent war a demand arose for a means of producing single flashes of light of extremely high intensity for night aerial photography of enemy occupied territory, and the desired result was obtained by the production of specially designed Xenon-filled flash tubes. The potentialities of the technique then employed were recognised as having fundamental importance in a wide field of applications, and a range of tubes, a brief description of which follows, has been developed to meet the requirements of those many operations that call for a light flash of very high intensity and brief duration.

Type 1.	Large helix of quartz tubing, suitable for extremely heavy loading.
2.	Hard glass helix for heavy loading
3.	Hard glass helix for lighter loading than type 2, suitable for use in portable equipment.
4, 5 & 6.	Hard glass straight tubes of different lengths and loadings.
7.	Hard glass tube for extremely short duration flashes.

* Manuscript received on December 11, 1947. Presented at a meeting of the Society on Tuesday, January 13, 1948.

Description

Generally speaking a flash discharge tube consists of a tube of hard-glass or quartz into the ends of which are sealed electrodes, the tube itself being filled with a rare gas at a low pressure.

It is an essential factor in the operation of low pressure discharge tubes as high intensity light sources that the current density in the discharge be high, and for the operation of flash tubes this high current density is obtained by discharging through the tube a condenser, previously charged to a relatively high voltage. The effect of this discharge is to produce a single flash of light of a luminous energy that is a function of the charge in the condenser and the charge voltage. Tubes may be operated in conditions in which these flashes are isolated from one another by relatively long periods of time, or they may follow one another in rapid succession.

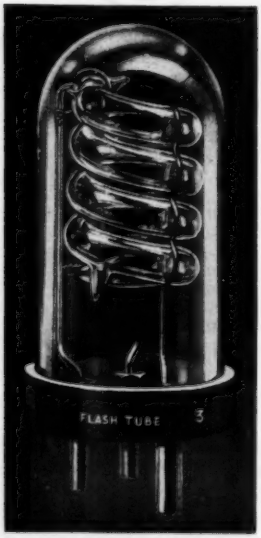

Fig. 1. Type 3 tube.

In such pulse conditions currents of considerable magnitude are produced and the instantaneous wattage dissipation may reach a very high order.

The energy discharged from a condenser into a flash tube can be calculated from the formula:—

$$\text{Energy in joules (watt-seconds)} = \frac{CV^2 \times 10^{-6}}{2}$$

Where C=condenser capacity in microfarads

V=voltage of condenser charge

If the result obtained from this energy calculation be divided by the time of discharge in seconds (t), we clearly arrive at the average power in watts:—

$$\text{Average power in watts} = \frac{CV^2 \times 10^{-6}}{2t}$$

In practice the full energy stored in the condenser is not received by the flash tube as there is always a small residual charge left in the condenser, but this is only of the order of 100 volts. There is also, of course, a certain consumption of energy due to ohmic losses in the conductors between the condenser and the tube. These total losses are small with well-designed equipment and for all practical purposes may be neglected.

Certain flash tubes are designed to have a breakdown voltage less than that to which the condenser is charged, and such tubes are kept isolated from the condenser until the flash is required. With this type energy losses in the switch may be high.

All those types of flash discharge tubes with which this paper is primarily concerned are designed with a breakdown voltage substantially higher than the condenser voltage, and are normally connected permanently across the condenser terminals. The striking of such a tube or "triggering" is effected by causing ionisation of the gas filling, this may be done by means of a high voltage spark as from an induction coil, or by a combination of high voltage and high frequency as produced by a Tesla coil. The high voltage pulse, of the order of 10,000 to 15,000 volts, is applied to a triggering electrode, which is either incorporated in the tube or may consist of a few

turns of wire wrapped round the tube. This pulse sets up electrostatic fields that cause initial ionisation inside the tube and start the discharge of the condenser.

It is important to note that current from the condenser starts to flow through the tube immediately the triggering pulse is applied, and rapidly builds

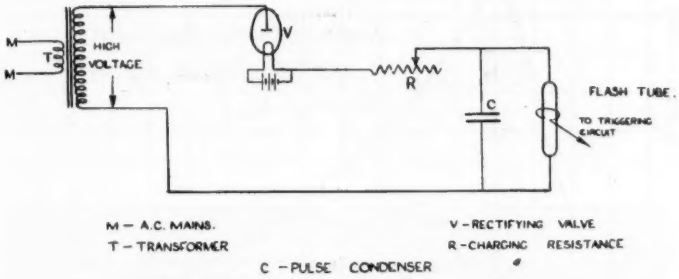

Fig. 2. Basic circuit for flash tube operation.

up to a very high value, the rate of increase being limited only by the ionisation time of the gas and the impedance of the circuit.

After reaching its maximum value the current dies down owing to the decreasing condenser voltage and the discharge finally extinguishes at about 100 volts. The whole effective discharge takes place in an extremely short space of time—of the order of from 1 to 1,500 micro-seconds—depending on the type of tube and its method of operation.

A typical light intensity-time curve is shown in Fig. 3.

Duration of Flash

The effective duration of flash from a flash discharge tube is approximately proportional to the condenser capacity, i.e., if the capacity of the condenser is reduced to one half the duration of flash will be reduced also to one half, provided the condenser charge voltage is kept constant. On the other hand if the condenser capacity be kept constant the flash duration will increase slightly with increasing voltage, but the increase in the flash duration is considerably less than proportional to the increase in voltage. It follows that with the voltages adjusted to give equal amounts of energy from two condensers, one of which is twice the capacity of the other, the duration of flash from the smaller condenser would be considerably less than that from the larger, and that for equal energy the highest speeds are obtained with a high voltage and low capacity.

It is extremely difficult to measure accurately the effective flash duration, peak light output, etc., of flash tubes owing to the very short time that the trace is visible on an oscillograph. It can, however, be taken that the effective duration of the flash, speaking photographically, of tubes types 2 to 6 at maximum loading and single flash conditions will be of the order of 100 to 200 micro-seconds, that of type 1 about 1,500 micro-seconds and of type 7, 1 to 2 micro-seconds.

For special purposes it may be desired to increase the duration of flash beyond that obtained with a normal circuit. This can be effected by including

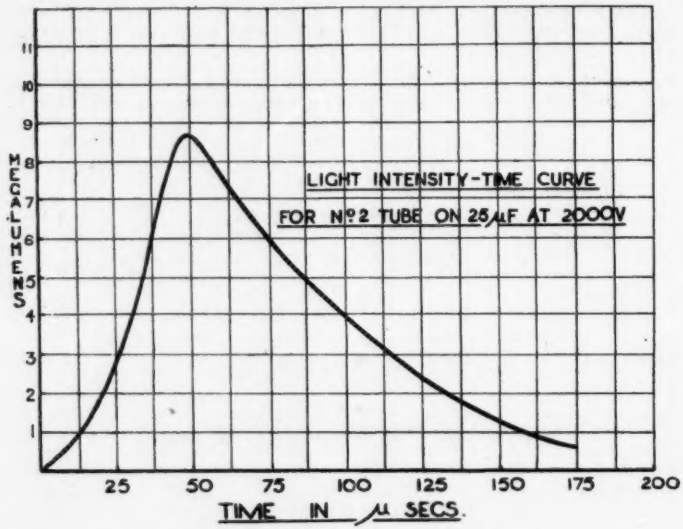

Fig. 3. Light intensity-time curve for type 2 tube.

an inductance in the circuit, but this expedient should only be resorted to with the utmost discretion, since the whole effectiveness of a flash tube, its high efficiency and spectral characteristics are dependent upon the very high current density discharge through the gas, and lengthening the duration of the flash can, of course, only be done at the expense of current density.

Colour of the Light and Gas Filling

As is well known, the colour of the light emitted by a pure mercury vapour electric discharge lamp is improved progressively as the current density in the arc is increased. Similarly, one of the effects of the very high current density in a flash tube is to produce light with extremely good colour rendering properties. The spectrum itself is very complex indeed consisting of a large

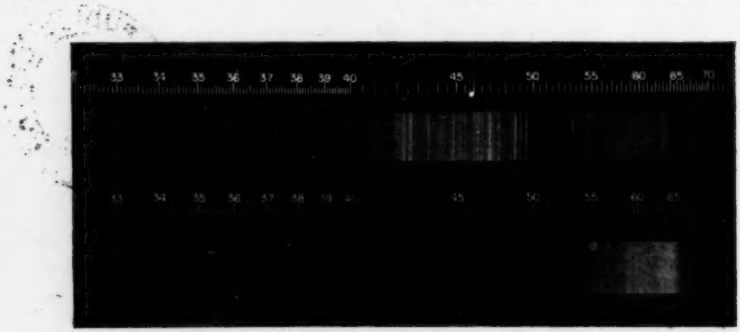

Fig. 4. Top — spectrum of xenon filled flash tube. Bottom — spectrum of sunlight.

number of strongly excited spectral lines and a considerable amount of continuous background, the total effect being such that for all practical purposes it can be looked upon as continuous.

Fig. 4 shows the spectrum of a xenon filled tube compared with that of sunlight. It is found that the very large number of spectral lines is typical of all gases when operating in flash conditions, but the balance of the xenon spectrum more nearly approximates to natural sunlight, and it is for this reason, now that adequate supplies of xenon have become available, that this particular gas is used in all flash discharge tubes in this range except where there are special reasons for the use of other gases.

For example, the flash tube type 7 is designed to produce a flash of light of extremely short duration for use in the study of such subjects as ballistics. The required effective flash duration is of the order of 1 to 2 micro-seconds and

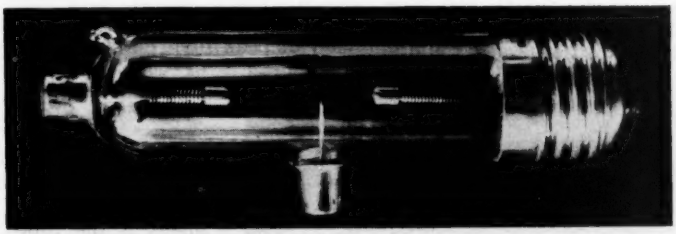

Fig. 5. Type 7 tube.

since, as we have seen, the highest flash speeds are obtained with high voltage and low capacity these are the conditions under which the tube must operate. In this case the use of an argon-nitrogen gas mixture enables the tube to be operated at 7.5 K.V. and this voltage with a 2 mfd capacity gives the objective flash duration with sufficient energy dissipation (56 joules) to photograph very high speed motion.

Colour Temperature

There appears to be a growing practice in America to relate the emission from all and every light source to colour temperature, expressed in degrees Kelvin. This is helpful only if the emission is such that it can be truly classified in this way.

There is a tendency to follow the same course in this country and without admitting the validity of this practice, particularly with the type of spectrum met in flash tube working, colour temperature measurements of flash discharge tube emission have been taken, and they indicate that an appropriate figure would be about 6,500 deg. K, but this figure should be treated as a rough guide only.

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Accuracy of Reproduction

A very important point that arises with regard to light sources used for photographic work is the accuracy of reproduction of the light output. In this respect Edgerton, a pioneer worker in America, has shown that, with a reasonable interval between flashes, a flash tube of the type described above can be used as a photometric standard, that is to say that provided the voltage and capacitance remain constant, the light output per flash is also constant.

It is easy to visualise instances when this fact can be put to useful effect, e.g., in the comparison of the speeds of different photographic emulsions.

Control of the Triggering Impulse

Control of the triggering impulse can, by the use of suitable electronic circuits, be effected by (a) switch, (b) microphone, or (c) light sensitive cell. Each method has its field of usefulness, but the first is, naturally, the one in most common use. The switch can be operated as a separate motion by hand, by the release mechanism of a camera shutter or other means. Circuits are in use in which the current through the switch is of the order of only a few micro-amperes at a very low voltage—in one case 47 micro-amperes at 4 volts—and such circuits are particularly suitable for linking up with the shutter mechanism of a camera.

When synchronising the flash with a camera shutter it is essential to remember that in a well-designed flash tube circuit the time lag between the initiation of discharge and the attainment of peak light output is of the order of 50 micro-seconds, and the flash becomes photographically effective earlier still. This means that with normal camera shutters the flash will occur before the shutter opens if the tube is triggered and the shutter release mechanism is operated at the same time. This calls for reversal of the technique used with photo flash bulbs where, owing to the "burning" time of the foil or wire, the bulb must be fired before the shutter is opened.

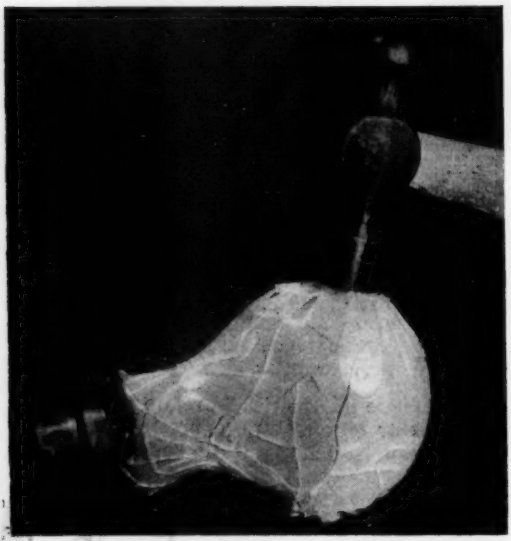

Fig. 6. Example of microphone triggering.

The uses of microphone triggering are obviously those where a noise is associated with the operation at the time the picture is required. In these cases it is usual to darken the room and open the camera shutter before the operation is set in motion. A very fine degree of control over the timing of the flash can be exercised by adjustment of the distance between the microphone and the seat of origin of the noise.

There do not appear to be many applications where photo-cell flash initiation is of much value, but it can be very usefully employed where it is desired to use a number of flash tubes for a single photograph. Ordinary commercial flash tube equipment for studio or equivalent use is commonly designed to operate up to two tubes of type 2. If a higher intensity than that given by these two tubes is called for, it is convenient to arrange for the additional equipment to be photo-cell operated, and for these latter units to act as

satellites to the switch-controlled master equipment. Camera-tube synchronisation is arranged between the camera shutter and the first equipment, the flashes from which cause the remaining tubes to be triggered. For the types of photographs to which this technique is applied, the delay between the flashing of the master tubes and the satellites is of no moment; it could not, of course, be used successfully where really high-speed movement is involved.

Loading of Flash Discharge Tubes

All types of flash tubes are suitable for use in single flash conditions. The recommended maximum loading to which each should be subjected is given, together with the operating conditions, etc., in Table 1.

Table 1

Type.	Voltage.	Condenser Capacity. (Mfds.)	Energy. (Joules.)	Approximate Lumen-Seconds.
1	4,000	2,000	16,000	640,000
2	2,000	200	400	16,000
3	2,000	50	100	4,000
4	2,000	100	200	8,000
5	2,000	60	120	4,800
6	2,000	30	60	2,400
7	7,500	2	56	—

It will be noted that the approximate efficiency of tubes of types 1 to 6 inclusive is in each case 40 lumens per watt. The light output of the type 7 tube in lumen-seconds is not yet established.

Overloading of a tube on single flashes causes crazing of the tube owing

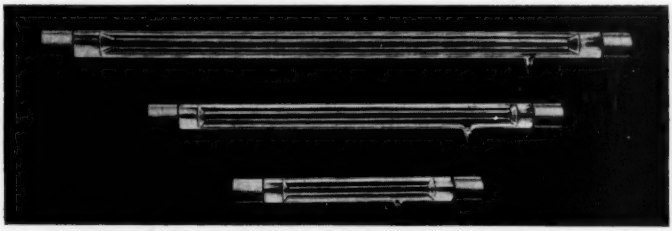

Fig. 7. Tubes type 4 (top), 5 and 6 (bottom).

to the over-violence of the discharge. This crazing appears to be due to actual melting of the inner surface of the tube, the cracks appearing when the tube cools down. If the crazing is not excessive the tube may continue to function, but will probably be difficult to start and is likely to behave erratically.

With quartz tubes, as type 1, the first visible signs of overloading are commonly seen as a white deposit on the inner surface. This white deposit is thought to be quartz that has been evaporated from the surface of the tube and afterwards condensed on to it.

When it is desired to operate a flash tube repetitively, as in a stroboscope, due precautions must be taken to ensure that the safe loading is not exceeded. It is clear that the watts consumption of a flash tube is the product of the watt-

seconds (joules) per flash and the number of flashes per second. For example, a type 3 tube operating at 2,000 volts and 50 mfd or 100 watt-seconds would, if flashed once per minute, have a watts input of $\frac{100}{60}$ or 1.7, but if it were operated at 10 flashes per second the input would be 10 x 100 or 1,000 watts. On repetitive flashing, overloading is likely, in the first instance, to cause the tube to miss, i.e., fail to flash, or it might become continuously conductive, whilst the excessive temperature rise may damage the tube itself, possibly raising it to its melting temperature.

It follows that, in order to keep the loading of such a tube within safe limits, it is necessary, since the operating voltage is a constant, to reduce the capacity of the pulse condenser as the frequency of flashing is increased.

The maximum permissible wattage loading of those flash tubes that are suitable for continuous flashing has been established and is given in Table 2.

Table 2

Flash Tube. Type.	Maximum Permissible Loading. (Watts.)
2	50
3	30
4	40
5	26
6	13

The capacity 'C' of a condenser charged to 2,000 volts, suitable for use with a tube flashing at any frequency "f," can be found from the formula:—

$$C = \frac{\text{Permissible wattage loading}}{2f}$$

The minimum flash frequency to which this formula may be applied is clearly that at which the condenser capacity at this frequency does not exceed the maximum value given in Table 1. For example, the type 2 tube has a maximum energy input of 400 joules and as the effective loading must be limited to 50 watts (*vide* Table 2) the minimum frequency is once every eight seconds.

The most suitable tubes for high frequency flashing are those with a small bore, the proximity of the tube walls to the arc very materially helping in the rapid de-ionization of the tube. On the other hand, the type 7 tube is not suitable for continuous loading as it readily becomes continuously conductive owing to its large internal diameter and short arc.

The figures for wattage loading given in Table 2 are based on the assumption that the tubes are operated in reasonably well ventilated conditions; if used for long periods in an enclosed space some allowance should be made or the temperature rise may become excessive.

There is no limit to the frequency with which light flashes can be produced, although each type of tube has its individual limitation imposed by its time of de-ionization. If the de-ionization time of the selected tube is too long to permit the required flashing rate being obtained from a single tube, a number of tubes operated by additional equipment can be arranged to flash in succession.

Danger and Safety

Those who use flash tube equipment must appreciate that such equipment can be a very real source of danger unless proper precautions are taken in its design and construction. A flash tube type 2 operating under the maximum, single flash loading of 200 mfd. and 2,000 volts, will pass an average

current throughout the full discharge period of the order of 400 amperes, with a peak value several times greater than this figure.

Like all potentially dangerous apparatus, this is perfectly safe if handled with discretion, and if the equipment is designed and manufactured by those who recognise their responsibility to the user and have sufficient knowledge to incorporate the essential safeguards in the design.

It is very necessary to stress this point as many people nowadays have more than a working knowledge of electronics as exemplified in wireless design and construction, and compared to the complexities of wireless apparatus a flash tube circuit looks, and is, attractively simple, if one is merely concerned with operating the tube. Therein lies the very real danger that amateurs and, be it said, others who would not like to be classed as amateurs may, in assembling such apparatus, produce equipment potentially dangerous to the operator. It is likely to be only a question of time, in such cases, before the user gets a severe shock or burn, if nothing worse.

Photography

Photography represents one of the most important fields of application of flash tubes. Tubes are available with a speed of flash capable of photographically arresting the motion even of such fast-moving objects as bullets and shells in flight. They can, therefore, be used to make permanent records of phases of movement, possibly after visual study of the complete cycle by stroboscopic inspection. The accuracy with which the flash can be timed ensures the correctness of the time base for ultimate analysis, whilst the methods, mechanical and otherwise, by which the initiation of ionization can be carried out are so varied that it is possible to synchronise the flash with any type of movement.

Effective use has been made of flashes synchronised with the shutter of a ciné camera to obtain pinpoint photographic analyses of motions, whilst it is not beyond the bounds of possibility that flash tubes may someday become the light sources for film projection. One can visualise the normal shutter being eliminated and frame changing taking place between light pulses. It would, no doubt, be necessary to arrange for several flashes to occur per frame to obviate objectionable flicker, but this would present no difficulty once a suitable type of tube had been evolved.

In the field of studio photography flash tubes offer outstanding advantages, in particular the naturalness of the photographs obtained because the subject has not to hold a pose or expression. The moment the photographer sees the expression, etc., that he wants he can register it on the negative. In this connection it is important to note that the flash is of such brief duration that the iris of the eye does not have time to react but remains, as far as the photograph is concerned, adapted to the same level of illumination as before. The flash tube technique is peculiarly valuable in child and animal photography.

In commercial photography in particular, and especially where colour photography is concerned, it is common practice to use high wattage lamps in projectors, which subject the model to unwanted radiant heat treatment which, if protracted, may have disastrous effects on make-up. When flash tubes are used no sensation of heat is experienced by the model.

For studio photography it is necessary to position and adjust the lighting to obtain the artistic effects of light and shadow, and a specially designed modelling lamp has been produced for this purpose (see Fig. 9). As will be seen, this lamp fits inside the helix of the type 2 flash tube, and when in

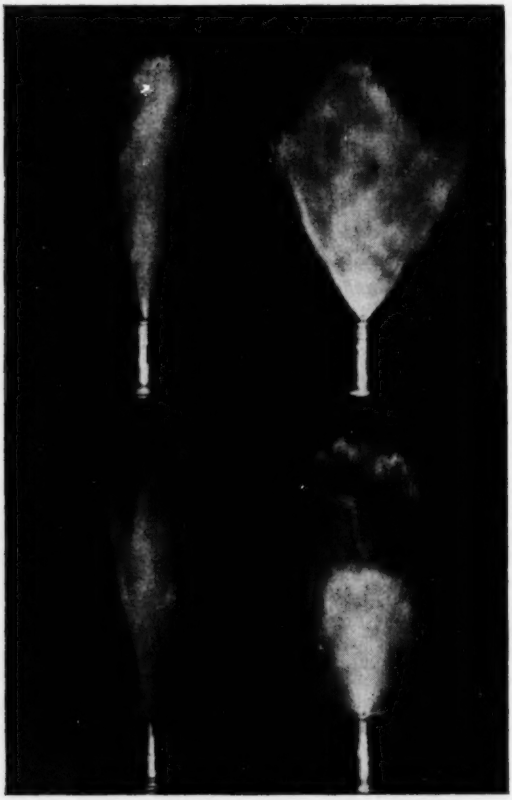

Fig. 8. Flash tube study of shape of vapour emitted by different jets.

position it has substantially the same light centre position as that of the tube itself. These modelling lamps are supplied for low voltage operation only, to give a suitable lamp filament design and to discourage the taking of the mains supply to the vicinity of the high voltage.

Many of the specimens handled by the photo-microscopist are easily destroyed by heat, and the difficulty long existed of obtaining sufficient light for an exposure that would stop all movement without raising the temperature to too high a level. The flash tube, with its very high intensity, little heat radiation and short duration flash provides a ready solution to this problem.

The certainty with which synchronisation can be effected and the dependability of the light output render flash tubes eminently suitable for press photography, and portable equipment incorporating the type 3 tube has been available for some considerable time. The weight is admittedly greater than press photographers have been used to carrying, but those who have adopted the system have done so because the advantages considerably outweigh this disadvantage. The heaviest component is the pulse condenser, and here it must

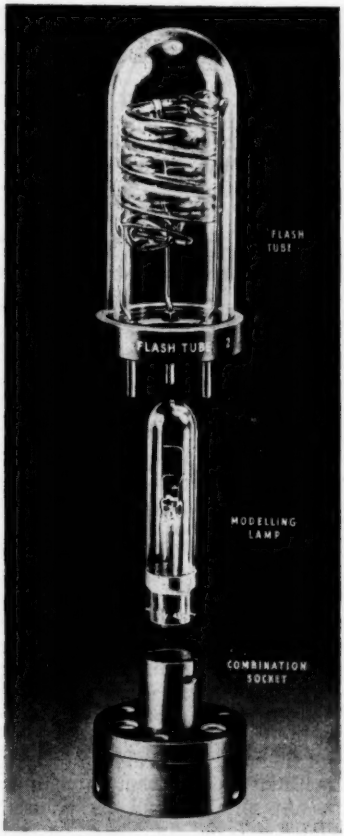

Fig. 9. Tube type 2 with modelling lamp.

be confessed that British condenser manufacturers have not yet succeeded in producing condensers that compare favourably as regards weight with those in use in America, where Pyranol and similar dielectrics have been adopted extensively in the interests of lightness.

The essential requirements of colour photography are colour quality of the illuminant and very high intensity lighting, several times the amount that is adequate for ordinary "black and white" work being necessary. The spectral quality of flash discharge tube emission is excellently suited to this purpose, whilst the intensity is only limited by the number of tubes available with equipment for their operation, it being an important factor that the necessary high value of illumination can be obtained without exposing the subject to excessive heat.

Stroboscopes

Stroboscopes of many kinds have long been available, but most of them have had too low a light output to allow of their operation at a distance from the object to be viewed, or in situations where the surrounding level of illumination is anything but low. The introduction of the modern high intensity flash tube has offered the scientist and engineer an instrument that they have not been slow to adopt. A very few of the purposes for which stroboscopes incorporating such tubes are now being used are:—

(a) the study of fuel injection systems,
(b) balancing vacuum cleaner armatures in conjunction with the Gisholt dynamic balancing machine,
(c) examination of the rotors of very high-speed turbines,
(d) loud-speaker cone design,
(e) studying the action of valves and their springs,
(f) synchronising wire recorders as used by the B.B.C.
(g) studying the operation of air turbines (30,000 r.p.m.) for mine lighting.

Acknowledgments

The author wishes to thank Messrs. Dawe Instruments, Ltd., and Messrs. Ernest Turner Electrical Instruments, Ltd., for the loan of demonstration equipment, and many other friends in the industry who placed at his disposal

information regarding their uses of flash discharge tubes. Finally, his thanks are due to the directors of Siemens Electric Lamps and Supplies, Ltd., for permission to present this paper, and to his colleagues in the Research Laboratories at Preston for assistance in its preparation.

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Discussion

DR. J. W. MITCHELL said that he would confine his remarks to the short duration type of discharge tube, referred to in the paper as type 7. His own personal experience was limited to this type and the author had dealt very adequately with the other types. The discharge tube acted as a triggering device which permitted the conversion of a definite amount of stored electrical energy into light energy at a determined instant. He could endorse the author's remarks about the constancy of the integrated light output from a discharge tube excited by a condenser discharge. The shape of the curve showing the variation of the light output with time depended mainly upon the constants of the electrical circuit but was also influenced by discharge tube design. For applications requiring a flash of extremely short effective photographic duration, it was necessary to produce a light output which rose from zero at a high rate to a high peak intensity, and then decayed rapidly to zero. The first requirement was met by using tubes with straight discharge channels in conjunction with non-inductive condensers. A spiral discharge channel acted as an effective inductance in the circuit which delayed the rise of current and reduced the peak intensity. With a given electrical circuit and design of tube, the duration of the discharge could be reduced by increasing the pressure of the gas filling. This could be done in tubes with straight discharge channels without introducing serious triggering difficulties. Those with coiled channels had to be filled at low pressures to permit effective triggering and because of this, together with the inductive influence of the tube, microsecond flashes could not be obtained with such designs. The tubes with which he had worked were filled with a mixture of argon and hydrogen at atmospheric pressure. To reduce triggering delays, it had been found necessary to introduce an internal triggering electrode in the form of a copper ring surrounding the cathode and to treat the electrodes with potassium during the processing of the tube. Tubes of this type had given effective microsecond flashes with delays on triggering of less than 0.5 microseconds when operated at the rated voltage. The flashes were used for photographing bullets and shells in flight.

The light output from a discharge tube filled with argon was largely in the blue-violet region during the early stages of the discharge. Longer wavelengths were emitted during the afterglow period. It was possible to reduce the effec-

tive photographic duration of the flash by using blue sensitive plates which were not affected by the longer wavelengths of the afterglow. Even when the discharge tube and the electrical circuits were of the best developed designs, the form of the light output curve with respect to time was still far from ideal on account of the relatively long decay from the maximum to zero. The best results in the photography of shells and bullets in flight could only be obtained if the characteristics of the light source were appreciated and photographic skill and technique used to minimise the imperfections. The photographers were, nevertheless, always grateful to those who had placed such valuable tools in their hands.

MR. G. T. PECK said the paper made it quite evident that in the flash discharge tube there was a new tool which was likely to be of increasing use both to the photographer in normal and high speed work and also in industrial applications. The designer of the apparatus embodying these tubes had two main problems to face, the first being the difficulty of weight. The condenser makers in this country were undoubtedly investigating the problem but, as far as he was aware, they still had a long way to go in the reduction of weight and size, though not perhaps so far in other respects. Equipment making use of these discharge tubes had not been manufactured in this country for much more than 18 months or two years and was, perhaps, still in its infancy. It was hoped that a reduction in weight and size would materialise in the not too distant future.

The other point on which he felt rather strongly was that of safety. The equipment maker was putting in the hands of the general public apparatus which operated at some ten times the voltage of any equipment they had been previously accustomed to. Although the circuits employed were basically quite simple he felt that in their apparent simplicity was to be found one of the pitfalls which might lead to trouble. In the infancy of any such new equipment any accident would be particularly regrettable and no trouble which the manufacturer could go to in order to ensure absolute safety under all conditions would be too much. He had seen instruction books—not printed in this country —which did not suggest that much attention had been given to this aspect. For instance, in one case it was stated that: "If anything goes wrong with this apparatus, leave it for one hour before touching it." In another such instruction book was a picture showing the user how to open the lid, when he was told to place a screwdriver across the condenser in case anything was wrong, and a note underneath saying: "Be careful to use a screwdriver with an insulated handle"! He suggested that such tactics were not in keeping with the very high standards of safety which this country had built up in the design, construction, and use of electrical apparatus, and he repeated that the books from which he had quoted were not of British origin.

Mr. A. G. PENNY remarked that the author had spoken a good deal about the applications of flash discharge tubes, but it would be interesting to hear a little more about the tubes themselves as there were many interesting technical details concerning them. The maximum permissible loading figures given by the author seemed to be very conservative and it would be useful to know how they were decided.

There was also the point that if the tube was overloaded there was crazing of the coil. Did that occur after one flash or, if after a number of flashes, how many? Was it possible to give one flash and then, perhaps, not another for half an hour, or could half a dozen flashes be given in quick succession?

The author had referred to the maximum time of flashing as once in 8 seconds. Whilst he himself was not a professional photographer, he could imagine that the Press photographer would often want to take more shots than one in 8 seconds. Would it be possible, for instance, to have one flash every three seconds without reduction in power of flash? He believed that condensers could be recharged in that time satisfactorily, but would the tubes stand it?

This led to a point which had not been mentioned, viz., what happened to the tube in due course? How long did it live? Did these tubes gradually fade away or did they stop suddenly and what was their life performance? If they were flashed, say, once a day would they give more flashes than if they were flashed once in 8 seconds?

It seemed to him that the flash duration up to 1,500 micro-seconds mentioned in the paper was a little on the short side for much photography. They had been shown a photograph of a girl turning a somersault, which was excellent from the academic angle, but he heard somebody remark that it could not be told whether the slide was put in upside down. There was no suggestion in the slide that the girl was actually moving, and he felt that from the artistic viewpoint there should be some impression of motion in such cases.

On the question of safety, he thought better results would be obtained if the apparatus was labelled "Dangerous." Users would then be careful. If the apparatus was likely to be lethal then users should be warned beforehand.

With regard to the modelling lamp with a very short light source, would it give the same light distribution as the very large flash tube helix when used in the reflectors shown, and also why was it desirable to have a low voltage modelling lamp? What was the objection to having a mains voltage lamp inside the flash tube?

Mr. R. W. KERSEY, referring to the duration of the flashes, said that with the short duration flash there was an oscillatory discharge from the condenser, whereas in the case of long flashes there was an ordinary direct discharge.

Referring to what Dr. Mitchell had said with regard to the variation in colour as between different portions of the discharge, he said that also occurred in the case of the photo-flash tube and it was interesting to examine the instantaneous light values by means of photo electric cells with appropriate filters.

He said he sympathised with the author in his difficulty of measuring and assigning any value of light intensity in the case of a micro-flash device. A certain amount of work had been done on that but values could not yet be quoted.

In conclusion he said that the micro-flash tube had given excellent results in war service and completely justified itself. Peace-time applications at the moment, however, did not seem to be so important. The long duration tube was a different proposition and entered into many other fields. There was the photographic field in particular, but later on it would become equally important in the industrial and engineering field because it could give a great amount of information, as well as a great amount of entertainment.

Mr. E. J. G. BEESON said the paper described a very fascinating subject because the discharge tube opened up a new field in photographic technique. The application of these flash tubes, both for stroboscopic and single flash work provided industry with a scientific tool enabling many problems to be solved with a minimum of effort.

It is interesting to look back on the development of these flash discharge tubes, as work carried out as early as 1932 by Edgerton showed that when a condenser was discharged through mercury vapour or argon gas, an appreciable amount of light was given off. From the early work various types of tube were developed, and one of the first stroboscopic lamps giving flashes of light of only a few microseconds duration was available in this country in 1934. The tube was designed for low voltage operation from the 110v. A.C. or 200v. A.C. mains and operated in a low pressure of mercury vapour or argon gas. At a frequency of 3,000 flashes per minute it had a life of some 3,000 hours, giving some thousands of millions of flashes.

Following these developments, and as the result of later work by Edgerton, the high voltage stroboscopic and single-flash discharge lamps had been designed, operating at very high loadings, and with their relative small source size and consequent increase in brightness they give a very high light output.

Continuing, he mentioned the possibilities of this new light source for medical photography, as it provided a very cool light source due to the very short duration of the flash and consequent low total energy and infra red radiation. A light source should also enable a true colour rendering to be obtained and here, due to the high current density in the discharge tube, the spectral radiation was almost continuous and a very good colour rendering with filters was possible.

Mr. J. G. HOLMES said that he could understand that a shock from the electrical equipment for this apparatus might be very unpleasant, but he wondered whether it would be sufficiently likely to cause death for it to be regarded as lethal. He also asked for information about the precautions necessary to reduce radio interference from these lamps.

Mr. F. W. DAWE said he could confirm what Mr. Peck had said on the question of safety although it might be some satisfaction to know that although there were some 500 of the small portable equipments in use in this country at the present time, no case of electric shock had been reported. In the case of the portable battery operated equipment the energy stored in the condenser is limited by size and weight restrictions but in the case of the mains-driven studio equipments there is a far greater degree of danger and a correspondingly greater degree of protection is necessary.

Continuing, he said it seemed that this type of photography would need the development of special film materials, particularly for colour work. The very short duration was not best suited to the normal colour film which had been developed to give correct contrast and colour balance with a light duration of the order of 20 or 50 milliseconds, as obtained with normal shutter openings and wire filled flash bulbs. But the very much shorter exposure provided by the electronic flash apparatus was a very different proposition especially from the point of view of colour photography, and therefore it seemed to him there was a new problem here for the photographic industry.

Speaking with regard to the life of tubes, the experience of his firm was that 20,000 flashes on a single flash type equipment was quite normal, although in actual life tests they had obtained more than that. It was difficult to give a life for stroboscopic operation; it depended on the effective loading of the tube. In the case of the type 3 tube, a life of several hundred hours could be obtained below the maximum loading figure of around 30 watts but if this was exceeded the life would fall off rapidly and might be as short as 10 hours. A previous speaker had raised the question of the minimum time that must elapse between

flashes. In the normal way this was controlled by the charging time of the reservoir condensers, say, 7 to 20 secs. For applications requiring a very rapid sequence of flashes it is necessary to use a number of lamps each with its own condenser which could be charged from a common power unit and triggered sequentially by some form of R.C. circuit or mechanical switch. Such a problem arose in the case of a bullet which had to be photographed in a number of positions on one plate.

The simplest method of overcoming the variation in light distribution arising from the different focus points of the modelling lamp and the flash tube is to frost the outside of the flash tube so that it takes the same light centre as the internal modelling light.

Mention had been made of the application of the flash tube to clinical work and he knew that several hospitals were using such flash equipment for "eye" photography with colour film. The speed of the flash is such that the eye and body reflexes are not perceptibly affected. Similar equipment has also been used for microscopic photography where the heat and duration of normal lighting would damage the subject.

DR. MITCHELL, referring to the point raised by Mr. Dawe regarding the variable photographic results obtained with discharge tube illumination and the desirability of the production of suitable emulsions, said that there was a fundamental difficulty in photographic work with discharge tube sources of illumination. The flashes were normally synchronised with a mechanical shutter operating at about 1/100th second. During the exposure, the plate or film received a short pre-exposure with the background illumination, and then the high intensity short duration flash exposure, followed by another exposure to the background illumination. It was known that if a short duration high intensity exposure was followed by a longer duration exposure at a lower intensity level, the developed photographic image was liable to show either very low contrast or even reversal. Some modern high-speed emulsions showed this effect, known as the Claydon effect, very markedly. These emulsions should be avoided as far as possible for flash photography. For the best results in flash photography, the background illumination should be maintained at the lowest possible intensity level, as the effect was most marked when the flash was used to supplement fairly high-level background illumination.

MR. C. S. PRIESTLEY said he had little knowledge of the electrical side, his interest being in the photographic side. His main objection to any apparatus of this sort was that the source of light was too small and he would like to see a very much larger area of light. Would such a source of light be suitable for photography when used with parabolic reflectors such as had been used in the old days when large reflectors were used and only reflected rays were employed? Even by using a visor on the reflector the rays of light would still be divergent and he thought the ideal light for portrait work should give rays as nearly parallel as possible. He said he regarded daylight as still being the best light source for this purpose. He also had some doubts about the actinic value of the light if only reflected light were used.

He said he would like the source of light to be considerably larger than the object he was photographing, and also the reflector so manufactured that the rays would be parallel instead of divergent.

MR. J. M. WALDRAM recalled a paper before the Society in the 1920s on Stroboscopy, in connection with which an interesting demonstration was given of the then available neon tubes. They gave, however, about as much light as

the warning lamp from the equipment now illustrated. The progress since had been most remarkable.

When he was at the American Illuminating Engineers' Convention there was a demonstration of flash tubes as airport approach lights, and that led him to ask whether any work had been done on the visual effects of very brief flashes of light, which appeared to open an enormous field for investigation. The author had shown one of the after-image phenomena which occurred, and if there had been more time it would have been possible to show some very remarkable results of after-image effects which had puzzled physiologists.

Claims had been made for the performance of light from flashed tubes. One was that when the eye was exposed accidentally to a very brief flash of light it recovered its adaptation more quickly than when exposed to a flash of corresponding lumen seconds longer duration. Did the author know of any work on the visual effect with these lamps?

Dr. J. N. ALDINGTON, commenting on the references that had been made to the historical aspect of discharge tubes, said it must be acknowledged that Fox Talbot himself took the first flash photograph with devices which, in principle, were identical with those which had been demonstrated that evening. He agreed with what had been said as to the debt owing to Prof. Edgerton, and due acknowledgment had been made in papers before the Society of his fundamental pioneer work.

Mention had been made of the relatively low infra-red output of these lamps, but he would like to correct any misunderstanding that might arise as the result of that statement. These lamps were extremely rich in the near infra-red, relatively more than any other discharge source, in the region of 7,000 to 12,000 Angstrom units, and use had been made of that in a number of applications which he was not in a position to describe at the moment.

Certain comments had been made which might lead to the impression that our condenser manufacturers were very much behind in this country. As a matter of fact, a great debt was owing to the condenser makers in this country for the great job of work they had done in this comparatively new field and in producing capacitors of great reliability.

Replying to the discussion the author thanked Dr. Mitchell for his interesting contribution. He noted that the tubes with which Dr. Mitchell had been working had activated electrodes and an argon-hydrogen gas filling. The tubes referred to in the paper as type 7 were designed to give a similar performance to that of those used by Dr. Mitchell but had non-activated electrodes and an argon-nitrogen gas mixture.

The suggestion had been made that the very short flash duration of such tubes could be made still shorter by filtering out the longer wavelengths emitted in the later stages of the discharge, but this was a matter that would appear to need further investigation.

He agreed with Mr. Peck on the points he had made. Condenser makers in this country had produced pulse condensers of a high standard of quality and performance, and were undoubtedly endeavouring to reduce the weight and size as far as was consistent with reliability. This matter was of particular importance where portable apparatus was concerned; a completely portable, battery operated equipment, suitable for Press photographic use, had been available for some considerable time but its popularity and usefulness would be greatly enhanced if the weight of the condenser were reduced by, say, 50 per cent.

With regard to safety, flash tube equipment involved principles and a technique with which comparatively few were fully conversant. He felt that a moral obligation rested on those who appreciated the potential dangers of unsound equipment to warn those who might not do so, and this was why he, himself, had stressed the safety aspect in the paper.

Replying to the suggestion made by Mr. Penny that the loading of the tubes, as given in the paper, was conservative, the author said that this was a matter that he had had under discussion for some time with his colleague, Dr. Aldington. Mr. Penny knew quite well how conservative research technicians tend to be. They preferred—and he thought they were right—to be somewhat over-cautious in the early stages of any development. It was essential to be quite sure of one's ground before starting to boost performance.

Crazing could be caused by a single flash if the energy dissipated were sufficiently high. It resulted from over-heating and appeared to be due to actual melting of the inner surface of the tube, hair cracks appearing when the tube cooled down. It could equally well occur from the cumulative heating effect of a number of flashes unless precautions were taken, on the lines stated in the paper, to limit the energy per flash to a safe figure. The time interval between flashes lies in the discretion of the operator, provided only that the permissible safe loading be not exceeded.

It was most unlikely that a Press photographer would miss taking a photograph merely in order not to jeopardise the tube life, but there would be a physical limit imposed on the frequency of operation by the time needed to recharge the condenser. Shortening of tube life would be less important than getting the photograph—a tube could be replaced, the photographic opportunity might never recur.

As to the life of tubes, a common reason for final failure to operate was the tube becoming continuously conductive owing to there being a deposit of metal, evaporated from the electrodes, on the inner surface of the tube. The end of life would often be heralded by missing, i.e., failure to flash, on occasions. Provided the operating conditions were constant, the life of a tube would be unaffected by the flash frequency.

The flash duration could be lengthened by including an inductance in series with the tube. Such an expedient must only be resorted to with discretion, because the efficiency of flash tubes was dependent on the current density in the discharge being very high and lengthening of the flash could only be done at the expense of current density.

He assured Mr. Penny that the slide of the girl turning a somersault was not put into the lantern upside down.

With regard to safety, every flash tube condenser should be fitted with a high resistance leak and this should be capable of discharging the condenser in less time than would be needed to open up the equipment.

As regards the modelling lamp, he said that low voltage operation helped considerably to overcome the difficulty of getting a good filament structure into the small space available. He disliked the idea of bringing the mains into the middle of the discharge tube and much preferred, on the score of safety, that the mains supply and high voltage side of the equipment be kept as far apart as possible. If it were felt that the distribution from the modelling lamp were insufficiently close to that from the flash tube, frosting of the outer glass cover of the latter would overcome the difficulty.

The author said that, whilst the early types of flash tubes referred to by Mr. Beeson may have given a very long life performance, the light emitted was insufficient for any but small area, close range working, and then only if the

surrounding brightness level was not too high. The modern high-definition stroboscope, incorporating the latest type flash tubes, could be used for large scale work, e.g., the inspection of aeroplane propellers for whip, etc., which would be quite outside the scope of the earlier tubes.

Mr. Beeson referred to the possibilities of these light sources for medical photography, and in this regard it was interesting to note that they were of interest also to dental surgeons, whilst their use in ophthalmology must not be overlooked.

Replying to Mr. Holmes, he said shocks from flash tube equipment could, quite definitely, be most unpleasant, the seriousness of the results from such a shock depended, of course, on how the shock was received and the physical condition of the recipient.

He had not investigated the effect of flash tubes on radio reception but would imagine that considerable interference might be experienced. The effect of single, isolated flashes would be transitory and could, no doubt, be disregarded, but steps might have to be taken to suppress interference where repetitive flashing was concerned. The interference would probably be produced chiefly by the triggering spark. If a filter circuit were used it should be on the wireless set and not on the flash tube circuit, as it would be undesirable to affect, in any way, the steep-fronted spark essential for good triggering.

The author said he was interested in Mr. Dawe's comments on the manner in which the life of a flash tube fell off with overloading; such facts showed the importance of not exceeding the loading recommended as a maximum by the manufacturer.

In reply to Mr. Priestly, the author pointed out that a flash tube is a light source and can be used in the same conditions as other types of light sources.

If all the light were reflected it would be advisable to ensure that the surface of the reflector did not absorb an undue amount of useful radiation.

Replying to Mr. Waldram, he said that the visual effect of very brief flashes of light had been under consideration for some time but he could not say how far the investigation had gone.

SESSIONAL MEETING IN LONDON

A sessional meeting was held at the Lighting Service Bureau, 2, Savoy-hill, London, W.C.2, at 6 p.m., on Tuesday, January 13, 1948, when the President (Dr. J. W. T. Walsh) took the chair.

The minutes of the last meeting were taken as read and approved, and particulars of the next meeting were announced.

The President then called upon Mr. C. R. Bickneil to present his paper entitled, "The Application of Modern Flash Discharge Tubes." The author first gave a description of the types of flash discharge tube available and dealt briefly with their physical characteristics. The author then discussed the operating conditions of such tubes and with the aid of a number of demonstrations described a number of applications.

After a vote of thanks, proposed by the President, had been carried the discussion was opened by Dr. J. W. Mitchell, who was followed by Mr. G. T. Peck, Mr. A. G. Penny, Mr. R. W. Kersey, Mr. E. J. G. Beeson, Mr. J. G. Holmes, Mr. F. W. Dawe, Mr. C. S. Priestley, Mr. J. M. Waldram, and Dr. J. N. Aldington. The author replied to each speaker in turn and the meeting was closed.

SESSION 1947-1948

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Members of Council :—

Dr. J. N. Aldington (1945)
Mr. C. J. ALLDERIDGE (1946)
Mr. C. R. BICKNELL (1947)
Mr. HAROLD BRIGHT (1947)
Mr. L. J. DAVIES (1946)
Mr. C. E. GREENSLADE (1946)
Dr. W. M. Hampton (1945)
Mr. A. G. Higgins (1945)
**Prof. T. David Jones* (1946)
Mr. T. S. JONES (1946)
Mr. S. D. LAY (1947)
Mr. H. A. LINGARD (1947)
Mr. E. W. Murray (1946)
Dr. J. H. NELSON (1947)
Mr. A. J. PASHLER (1946)
Mr. A. G. PENNY (1946)
Mr. E. B. Sawyer (1945)
Mr. J. S. SMYTH (1947)
Mr. J. F. STANLEY (1947)
Mr. W. R. STEVENS (1946)
Dr. W. S. Stiles (1945)
Mr. P. CRAWFORD SUGG (1947)
Mr. F. WALKER (1946)
Dr. W. D. Wright (1945)

Representatives of Areas :—
(ex-officio)

Bath & Bristol — Mr. E. A. NEWBURN
Birmingham — Mr. W. J. P. WATSON
Cardiff — Mr. J. TREVOR JONES
Edinburgh — PROF. M. G. SAY
Glasgow — Mr. V. P. MACNAUGHTON
Gloucester & Cheltenham — Mr. W. CHARD
Leeds — Mr. E. A. FOWLER
Leicester — Mr. J. G. EVERETT
Liverpool — Mr. T. R. JONES
Manchester — Mr. J. H. MORRISON
Newcastle — Mr. C. FIELDING
Nottingham — Mr. J. C. CHARITY
Sheffield — Mr. E. G. R. TAYLOR

Hon. Treasurer :—
Mr. J. G. Holmes (1947)

Hon. Secretary :—
Mr. H. C. Weston (1947)

Hon. Editor of Transactions :—
Dr. S. English (1947)

* Deceased.

The names in italics are those of Officers or Members retiring in 1948. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

ELECTION OF OFFICERS AND COUNCIL

SESSION 1948—1949. OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon Secretary, Hon. Editor of Transactions, and Ordinary Members of Council, is presented below for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48):—

> "After the issue of the Council's list, and not later than the 15*th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nomination in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Nominated by the Council to fill Vacancies :—

***President* :—**

Mr. J. M. WALDRAM, B.SC., A.C.G.I., F.I.E.S.

Vice-Presidents :—

Dr. E. C. WALTON, B.ENG., A.M.I.E.E.

Mr. E. W. MURRAY, A.M.I.E.E., F.I.E.S.

Dr. J. N. ALDINGTON, B.SC., PH.D., F.R.I.C., F.INST.P., F.I.E.S.

***Members of Council* :—**

Mr. A. D. S. ATKINSON
(Chief Asst., Lighting Service Bureau, London).

Mr. H. S. BARLOW
(Head of Physics and Maths. Dept., South-East Essex County Technical School).

Mr. G. H. GILES
(Secretary, British Optical Association).

Dr. H. F. GILLBE
(Inspector of Lighting, Ministry of Transport).

Mr. E. C. LENNOX
(Deputy Engineer, Lighting and Heating Dept., North-Eastern Electric Supply Company).

Mr. L. C. RETTIG
(Manager, Technical Advisory Service Dept., H. R. Cleave and Co.).

Mr. W. T. F. SOUTER
(General Sales Manager, Holophane Ltd.).

Mr. S. G. TURNER
(Illuminating Engineer, Metropolitan-Vickers Electrical Company, Ltd.).

***Representatives of Centres* :—**
(ex-officio)

To be appointed before October 1, 1948.

***Hon. Treasurer* :—**
Mr. J. G. HOLMES

***Hon. Secretary* :—**
Mr. H. C. WESTON

***Hon. Editor of Transactions* :—**
Mr. W. R. STEVENS

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

CORPORATE MEMBERS:—

Bass, R. J. .....116, Diana Street, Roath Park, CARDIFF.
Bibby, R. A. .....5, Arundel Road, Worthing, SUSSEX.
Bicker, H. F. G. .....“Elbian,” Fairfield Avenue, Whipton, EXETER.
Bloxsidge, W. R. .....28, Quebec Road, Ilford, ESSEX.
Bond, T. A. .....512, Huddersfield Road, Wyke, Bradford, YORKS.
Brooks, W. .....142, Bradford Street, Bolton, LANCS.
Bywaters, F. R. .....333, Victoria Road, Ruislip, MIDDX.
Chowdhry, S. N. .....18/43, Dover Lane, P.O. Rashbihari Avenue, Calcutta, 29, INDIA.
Christie, T. M. .....“Tregenna,” Harrow Road, Wembley, MIDDX.
Crow, D. R. .....3, Greendale Green Avenue, LONDON, N.W.7.
Davies, A. J. .....31, Heol Pantycelyn, Whitchurch, GLAM.
Day, T. J. .....224, Whitton Road, Twickenham, MIDDX.
Deane, A. E. .....156, King Edward Avenue, Worthing, SUSSEX.
Doughty, H. J. .....52, Mynors Street, STAFFORD.
Edwards, H. C. .....283, Alderman Road, Knightswood, GLASGOW, W.
Farrall, C. .....261, Sarehole Road, BIRMINGHAM, 28.
Harvey, A. F. .....48, Barnett Road, Brighton, SUSSEX.
Honeybun, E. J. .....31, Cyn Coed Road, CARDIFF.
Hood, R. A. .....23, Fountainhall Road, EDINBURGH, 9.
Hume, H. M. .....c/o Philips Electrical, Ltd., 61, Frederick Street, EDINBURGH, 2.
Humphreys, W. A. .....47, Lavender Avenue, KINGSBURY, N.W.9.
Jones, E. P. .....“Langside,” Den Avenue, Bognor Regis, SUSSEX.
Karanth, K. P. .....The Industrial Equipment Co., 95, Balepet, Bangalore City, INDIA.
Levey, G. W. S. .....1, Glenavon Crescent, Porthcawl, GLAM.
Lewis, C. C. .....25, Torquay Road, Paignton, DEVON.
Lines, J. T. .....48, Marshall Grove, Perry Barr, BIRMINGHAM.
Longhurst, W. D. H. .....26, Westridge Road, Kings Heath, BIRMINGHAM.
McFarlane, J. .....82, Kilpatrick Gardens, Clarkston, RENFREWSHIRE.
Mackie, T. L. .....8, Heythrop Grove, Moseley, BIRMINGHAM.
Margetts, E. R. .....129, Oxford Road, Kidlington, OXON.
Maundrell, R. T. .....11, St. Thomas's Road, Worthing, SUSSEX.
Mellor, H. B. .....c/o British Thomson-Houston Co., Ltd., 46, Wellington Street, LEEDS, 1.
Mitchard, A. E. .....30, Ashgrove, Pensedown, St. Johns, BATH.
Nelson, C. .....41, Mulgrave Road, MIDDLESBROUGH.
Nielsen, J. H. .....281, Cardigan Terrace, Coatsworth Road, Gateshead, 8, Co. DURHAM.
Oates, D. .....8, Haycliffe Drive, Great Horton, Bradford, YORKS.
Owen, G. J. .....217, Station Road, Knowle, WARWICKS.
Page, F. V. .....8, Hallside Road, Forty Hill, Enfield, MIDDX.
Ritchie, W. .....4, Featherhall Grove, EDINBURGH, 12.
Smith, C. C. .....“Vrondeg,” Hillfoot Road, Woolton, LIVERPOOL.
Styles, C. B. .....242, Bricknell Avenue, Hull, YORKS.
Wallwork, A. L. .....7, Lancaster Place, Blackburn, LANCS.
Walshaw, J. V. .....116, Spencer Place, LEEDS, 7.
Westaway, E. J. .....47, The Grove, PALMERS GREEN, N.13.
Wills, E. L. .....17, Cowick Lane, EXETER.

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